APPENDIX D

RIPARIAN HABITAT ANALYSES

1. Introduction

In forested watersheds throughout the Pacific Northwest, the protection of riparian areas is considered critical to the long-term health of aquatic ecosystems (FEMAT, 1993; Cederholm, 1994; Murphy, 1995). The protection of riparian areas is usually implemented by restricting management activities within an area adjacent to water bodies referred to as the riparian management zone or RMZ. Management within the RMZ usually involves the delineation of the RMZ (or several zones within the RMZ) and the development of restrictions on management activities within the RMZ (or its zones). The three alternatives under consideration in the Forest and Fish Report EIS represent different strategies for protecting riparian areas using different RMZ prescriptions and widths. In order to compare these alternatives quantitatively in the EIS, they were modeled both spatially, using the sample sections described in Appendix A, and at specific locations over time, using representative stands for different locales within the state. This appendix describes the modeling approaches used for the quantitative comparisons. A total of three separate analyses are described in the following sections. These include: 1) quantifying RMZ areas protected under each alternative; 2) applying the Large Woody Debris (LWD) Equivalent Buffer Area Index (EBAI) to each alternative; and 3) applying the Sediment EBAI to each alternative. Included in each analysis is an introduction, the rationale for the analysis, the assumptions made for the analysis, and the results of the analysis. For some of the analyses (e.g., the LWD EBAI) there are multiple steps with separate assumptions; these are described for each step.

2. Quantification of RMZ Areas

2.1 Introduction

Chapter 2 of this EIS provides a detailed description of how the RMZs are delineated and protected under each alternative. This section describes how the RMZ zones for each alternative were modeled spatially across the landscape so that an estimate of the amount of area protected within each zone, could be calculated. The spatial modeling was conducted using the sample sections described in Appendix A.

As outlined in Appendix B (Water Typing), each alternative proposes to use different water typing systems. The RMZ rules for each alternative vary by water type. Under Alternatives 1 and 2, RMZ width is based on channel width, as well as water type. Modeling the effects of the different RMZ rules required making assumptions about: (1) the channel width associated with each water type; (2) the situations where the shade rule would be implemented; and (3) what types of forest practices

occur adjacent to the RMZ. Differences in harvest prescriptions within the RMZs are assessed qualitatively. The sections below describe each assumption, as well as the rationale for making it.

As a general caveat: we emphasize that in many cases these are generalized assumptions for modeling purposes only. We acknowledge that many site-specific factors could result in more or less protection of each sample section under the different alternatives. However, since the goal of this analysis is to provide an objective, quantifiable and reproducible comparison of the alternatives across Washington State (as opposed to an exact prediction of the effects on each sample section), these assumptions are necessary and appropriate.

Modeling RMZ areas involved a number of tasks and steps, in addition to making a number of assumptions. Task 1 was defining stream widths, and Tasks 2, 3, and 4 involved defining RMZ areas protected under Alternatives 1, 2, and 3.

2.2 Task 1 - Defining Stream Widths

2.2.1 Rationale

Because RMZ widths for some alternatives are dependent upon stream widths as well as water typing, it was necessary to assign a representative stream width to each stream type in order to compare the total area protected by RMZs under each alternative.

2.2.2 Assumptions

To establish a "representative" (average) bankfull width by stream type, stratified by east and west side, the following assumptions were made:

- Ordinary high water mark (OHWM) (FPB, 1998) is considered equal to bankfull width (Rosgen, 1996).
- Type 1 streams were divided into two categories:
- Type 1a streams include the type 1 streams that are mapped as double-lines in the DNR Hydrography layer. Based on review of the double line streams in our sample section we determined double line streams were greater than 75 feet wide.
- Type 1b streams include all other Type 1 streams in the DNR hydrography layer that are represented as single lines. The TFW report 1988-90 Cumulative Report-data appendix (WDW 1991) was used to define the average width of these type 1b streams. This document collected stream width data across Washington State and calculated the average stream width by stream type stratified by east and west side.
- Type 2 streams include all streams designated as Type 2 streams in the DNR hydrography layer. The TFW report 1988-90 Cumulative Report-data appendix (WDW 1991) was used to define the average stream width of type 2 streams stratified by east side and west side of the state.
- Type 3 streams include all streams designated as Type 3 streams in the DNR hydrography layer. The TFW report 1988-90 Cumulative Report-data appendix (WDW 1991) was used to define the average stream width of type 3 streams stratified by east side and west side of the state.

- Type 4 streams include all streams designated as Type 4 streams in the DNR hydrography layer. It was assumed that bankfull width for all Types 4 streams are 5 feet or less. The TFW report 1988-90 Cumulative Report-data appendix (WDW 1991) did not calculate average bankfull widths for Type 4 streams. For modeling purposes it was decided to use the maximum width rather than the average since there was no data available to provide guidance on the average width of Type 4 streams.

- Type 5 streams include all streams designated as Type 5 streams in the DNR hydrography layer. It was assumed that bankfull width for Type 5 streams are 2 feet or less. The TFW report 1988-90 Cumulative Report-data appendix (WDW 1991) did not calculate average bankfull widths for Type 5 streams. For modeling purposes it was decided to use the maximum width rather than the average since there was no data available to provide guidance on the average width for Type 5 streams.

Table 1 presents the average bankfull widths used for modeling RMZ areas for alternative analyses that required a defined stream width.

Table 1. Bankfull Widths by Stream Type and Region Used for Modeling RMZ Areas

	Bankfull Width (feet)					
Region	**Type 1a**	**Type 1b**	**Type 2**	**Type 3**	**Type 4**	**Type 5**
East side	>75 ft	45	25	12	<5	<2
West side	> 75 ft	44	31	15	<5	<2

2.3 Task 2 - Modeling RMZ Areas Protected Under Alternative 1

There are many factors that influence RMZ widths under Alternative 1 that could not be readily applied using our generalized GIS-based analysis of sample sections (e.g., differentiating between cobble streams and bedrock streams, whether the shade rule is implemented resulting in maximum buffer widths and potentially more restrictive leave tree requirements, etc.). The assumptions that are defined below for the westside and eastside RMZs were peer reviewed by DNR foresters that enforce these rules out in the field (Personal communication Joe Blazek-DNR eastside forester, Sue Casey-DNR westside forester, October, 1999). It is recognized that these are generalized assumptions for modeling purposes and that many site-specific factors may result in more or less protection than applied in this exercise. However, the following assumptions were made to quantify acres of RMZs under Alternative 1.

2.3.1 Assumptions

- The shade rule of the Forest Practices Board Manual Section 1 must be applied to all RMZs if harvest is to occur within the maximum RMZ.

- The shade rule is based upon the premise that higher elevation streams naturally have cooler waters and thus need less of a canopy to maintain temperature because elevation is the primary controller of temperature at higher elevations; canopy becomes a greater issue at middle and lower elevations.

- The figures for the 16 degree C water temperature curve for canopy cover in the Forest Practices Board Manual Section 1 for both the east and west side (WAC 222-30-040(2) were used to select the threshold where the shade rule would be implemented based on the percent canopy requirement.

- Because the shade rule curve is based on elevations (streams at higher elevations tend to be cooler), for modeling purposes the percent shade needed to meet the water quality standards was broken into three divisions which are described in the next three bullets.

- The elevation at 20 percent shade (greater than 3,000 feet on the west side and 4,000 feet on the east side) would be modeled with the minimum RMZ; it was assumed that the minimum leave tree requirement within the minimum RMZ would provide the 20 percent canopy that is considered acceptable under the shade rule for both the east side and west side. This assumption was confirmed by DNR foresters Joe Blazek and Sue Casey (personal communication, October, 1999).

- At lower elevations, a greater percentage of canopy is needed to meet the shade rule. It was assumed that the maximum RMZ is needed to meet the 80 percent canopy requirement. The elevations necessary to meet the 80 percent canopy requirement are 750 feet and below on the west side and 2,750 feet and below on the east side. In most cases, the RMZ is not harvested, but in other cases some trees may be removed. It was decided that for lower elevation sites to meet the shade rule, the maximum RMZ would be modeled but with some type of selective harvest . Therefore, to account for several variations in low elevation RMZ determination and harvest, it was assumed that within the maximum RMZ, more trees must be left than the minimum leave tree requirement within the maximum RMZ to meet the 80 percent canopy and therefore were quantified by GIS as "Increased Leave Tree" (see Figure 1a). This assumption was considered plausible by the DNR foresters.

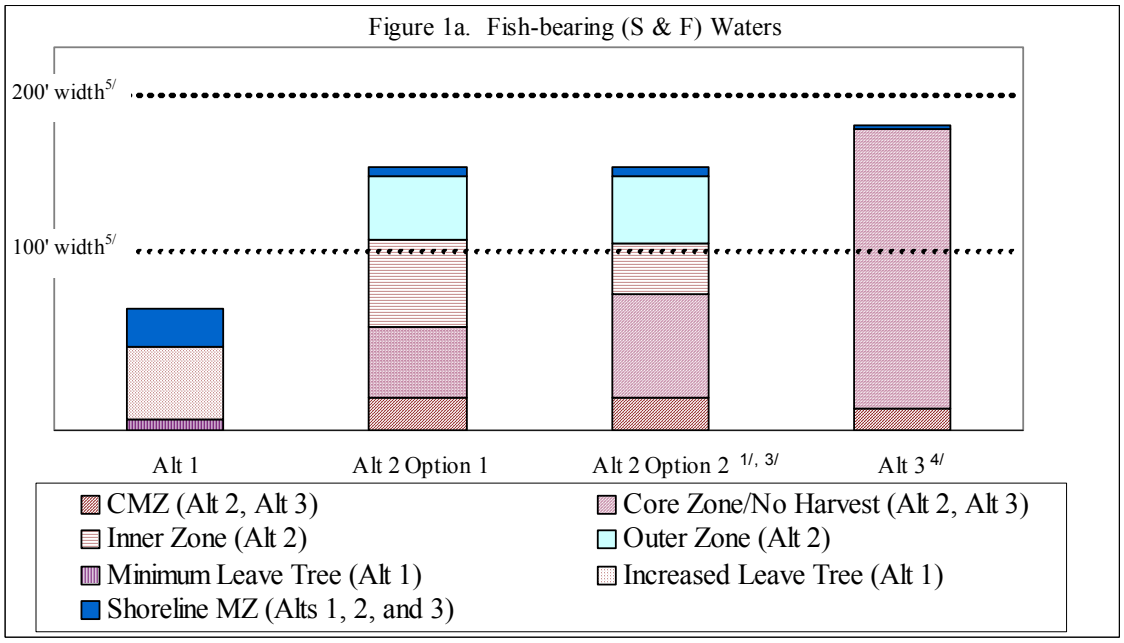
- At mid-elevations, canopy levels of 20 to 80 percent could be obtained with the minimum leave tree requirement from RMZ widths that are in the mid-range of the minimum and maximum RMZs. Therefore, at middle elevations, (between 20 and 80 percent canopy), it was assumed that the RMZ would need to be extended to 40 ft. to meet the shade requirement, but minimum leave tree requirements would be implemented, for both east side and west side areas. The 40-foot RMZ is an average between the 25-foot minimum RMZ and 75-foot maximum RMZ for Type 1 and 2 streams on the west side and between the 30 ft and 50 foot minimum and maximum RMZ on the east side for partial-cut harvest (which was assumed for quantification by GIS). All Type 1a streams (double line streams in the hydrography) on the west side greater than a 75-foot width tend to be at lower elevations and would be modeled with the maximum RMZs (100 feet on the west side). On the east side, unlike the west side, when implementing RMZ prescriptions, there is no differentiation based on stream width and, therefore, Type 1 double-line streams (see Table 3) were treated as Type 1 single line streams when quantifying RMZ areas.

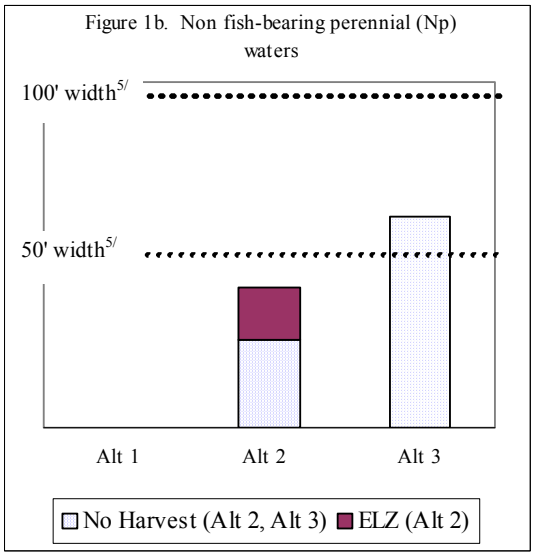
Tables 2 and 3 show the RMZs widths and types of harvest that were used to model Alternative 1 for west side and east side sample sections, respectively.

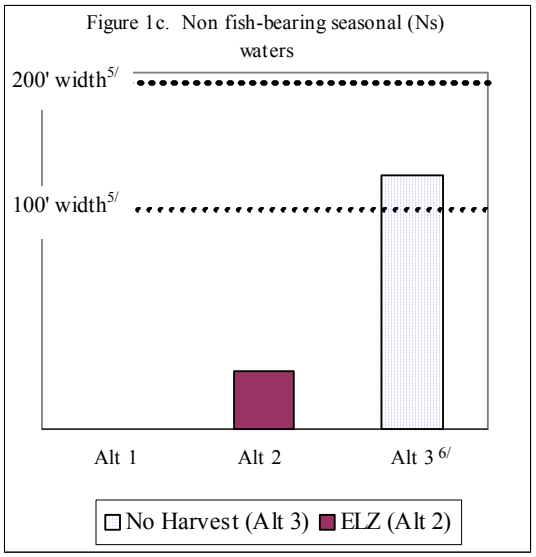
2.4 Task 3 - Modeling RMZ Areas Protected Under Alternative 2

Alternative 2 incorporates many factors that influence RMZ widths and that can not be directly modeled without taking a number of steps and making a number of assumptions. Therefore, the following steps were taken and assumptions were made to quantify acres of RMZs under Alternative 2.

Figure 1. Total Riparian Area Protection for Westside Waters by Alternative and Harvest Prescription
(Note: Histograms have been standardized by estimating total acreage in each protection category and then converting it back to the average RMZ width required to cover that acreage.)







1/ For Alt 2, this does not include implementing the shade rule. Also, all harvest across the landscape will be a mix of Option 1 and Option 2, rather than consisting entirely of either option; each option was modeled separately to capture the differences between the two options.

2/ For Alt 2 Option 1, 17% of the inner zone overlaps with the SMZ and 13% overlaps with the outer zone.

3/ For Alt 2 Option 2, 16% of the inner zone overlaps with the SMZ and 15% overlaps with the outer zone.

4/ Although most fish-bearing streams under Alternative 3 receive a 200-foot RMZ, some stream miles were greater than 20% gradient, and therefore received a RMZ less than 200 feet. This accounts for the failure of the Alt 3 RMZ acreage to meet the 200-foot buffer standard in this figure.

5/ Standardized 50', 100' and 200' buffers were applied to all stream miles, to facilitate comparison among alternatives.

6/ A large proportion of nonfish-bearing seasonal streams were 0-20% gradient under Alternative 3 and therefore receive a 200-foot RMZ. This accounts for Alt 3 RMZ acreage exceeding the 100-foot buffer standard in this figure.

Table 2. Westside RMZ Widths and Harvest Types Used to Model RMZ Areas for Alternative 1

Water Type	Elevation Classes (ft)	RMZ Width (ft)	Type of Harvest
Type 1a	< 3,000[1/]	100	Increased leave tree requirement
Types 1b and 2	> 3,000	25	Minimum leave tree requirement
	750 – 3,000	40	Minimum leave tree requirement
	< 750	75	Increased leave tree requirement
Type 3	> 3,000	25	Minimum leave tree requirement
	750 – 3,000	40	Minimum leave tree requirement
	< 750	50	Increased leave tree requirement
Types 4[2/] and 5	All	None	Clearcut

1/ No Type 1a streams were located above the 3,000 foot elevation.
2/ Type 4 streams may have a 25-foot buffer based on DNR discretion, this was not quantified since it is dependent on site-specific conditions that are not detectable at the landscape level.

Table 3. Eastside RMZ Widths and Harvest Types Used to Model RMZ Areas for Alternative 1

Water Type	Elevation Classes (ft)	RMZ Width (ft)	Type of Harvest
Types 1a, 1b, 2, & 3	> 4000	30	Minimum leave tree requirement
	2750 – 4000	40	Minimum leave tree requirement
	< 2750	50	Increased leave tree requirement
Types 4 and 5	All	None	Selective harvest

2.4.1 Step 1

To quantify RMZs by width and harvest prescriptions under Alternative 2, Types S, F, N_p, and N_s streams were separated by east and west side following the east and west side boundaries defined in the Forest and Fish Report (which follow the cascade crest).

2.4.2 Step 2

The topography, hydrography, and other information was reviewed by a hydrologist for every sample section and channel migration zones (CMZs) were defined for Type 1 and Type 2 streams that displayed meander patterns or that were known to be large streams in flat regions of the state. The Alternative 2 definitions were used to delineate the CMZ, and are included in Table 4, below. On the larger streams with large meanders, the meander belt width was used as the CMZ. On unconfined streams in flat regions, a CMZ was delineated that appeared to meet the Alternative 2 criteria.

2.4.3 Step 3

The following assumptions were applied based on stream type and region.

2.4.4 Assumptions for Types S and F Streams – West Side and East Side

- The DNR site class layer, modified by Foster Wheeler Environmental, was used to define RMZ buffer widths for Types S and F streams on the sample sections using the widths defined in the Forest and Fish Report. In addition, the stream widths defined in Table 1 were used to apply the RMZs to Types S and F streams.

Table 4. Channel Migration Zones Defined Under Alternative 2 (Forests & Fish 1999)

Channel Migration Situation	Stream Type	Stream Gradient	CMZ Characteristics
Moderately confined streams < 50 ft width	F	< 8% and >2%	❖ CMZ =< 4 feet channel width ❖ Primarily hardwood vegetation ❖ Well-defined break in slope at CMZ boundary
Unconfined streams < 50 ft width	F	< 8 %	❖ CMZ = mainstem + sidechannels ❖ Mixed hardwood and conifer ❖ Numerous active and abandoned side-channels
Unconfined meandering streams > 50 ft width	S	< 2 %	❖ CMZ = amplitude of meander wave OR meander rate X years to growth of functional size LWD ❖ Remnant side-channels and oxbow lakes
Unconfined braided streams > 50 ft width	S	< 2 %	❖ CMZ = bankfull width ❖ Sparsely vegetated with hardwoods ❖ Common in glacially-fed rivers
Unconfined avulsing streams > 50 ft width	S	< 2 %	❖ CMZ = valley bottom ❖ Lowland large river systems ❖ Dikes and levees common ❖ Mixed land use

(Source: Forests and Fish Report, Appendix A)

- For westside Types S and F streams under Option 1, the RMZ widths listed in Table 5 were applied. For westside Types S and F streams under Option 2, the RMZ widths listed in Table 6 were applied. For westside Type S and F streams, Option 2 is not applicable for site class III areas along streams >10 ft. or site class IV and V areas along all streams; therefore, these cases were not modeled (Personal Communication, Stephen Bernath, Oct. 1999). Because of this, only Option 1 was applied in areas where Option 2 was not applicable.

- For eastside Types S and F streams, the RMZ widths defined in Table 7 were applied in the High Elevation zone. The High Elevation zone followed the same prescriptions described for the westside Option 1. Option 2 is not an option for the eastside High Elevation zone. For eastside Type S and F streams, the RMZ widths defined in Table 8 were applied in the Ponderosa Pine and Mixed Conifer zones.

- For eastside Types S and F streams within the bull trout range, all available shade is to be retained within 75 feet of the bankfull width or CMZ of the stream. As a result of this rule, the 45 feet of inner zone that is adjacent to the 30 foot core zone that fall within the bull trout overlay will be given an additional level of scrutiny to ensure that all available shade is maintained. In some scenarios there is the potential that more restrictive harvest would be maintained when compared to the inner zone baseline prescriptions. To provide a perspective of the proportion of the inner zone on the east side that fall within the bull trout overlay the GIS quantified the area as defined in Table 9.

Table 5 presents how the RMZ zonation was defined for westside Type S and F streams of different size classes for Option 1 of Alternative 2; Table 6 presents the same information for Option 2. Eastside RMZ zonation is presented for the High Elevation zone in Table 7, for the Mixed Conifer and Ponderosa Pine zones in Table 8, and within the bull trout range in Table 9. The width of each zone is summed to obtain the total RMZ width, which is measured from bankful width or CMZ edge to the outer edge of the outer zone.

Table 5. Westside RMZs for Types S and F Streams Under Option 1 (thinning from below) of Alternative 2 for Streams ≤10 Feet and >10 Feet Wide

	Type of Harvest						
	Core Zone Width in Feet (No Harvest)		Inner Zone Width in Feet (Thinning from Below)		Outer Zone Width in Feet (Intensive Harvest with Leave Trees)		
Site class	Streams ≤10 Feet Wide	Streams >10 Feet Wide	Streams ≤10 Feet Wide	Streams >10 Feet Wide	Streams ≤10 Feet Wide	Streams >10 Feet Wide	Total RMZ Width in Feet
I	50'	50'	83'	100'	67'	50'	200'
II	50'	50'	63'	78'	57'	42'	170'
III	50'	50'	43'	55'	47'	35'	140'
IV	50'	50'	23'	33'	37	27’	110'
V	50'	50'	10'	18'	30	22’	90'

Table 6. Westside RMZs for Types S and F Streams Under Option 2 (leaving trees closest to the water) of Alternative 2 for Streams ≤10 Feet and >10 Feet Wide

	Type of Harvest								
	Core Zone Width in Feet (No Harvest)		Minimum Floor Width in Feet (No Harvest)		Inner Zone Width in Feet (Thinning)		Outer Zone Width in Feet (Intensive Harvest with Leave Trees)		
Site Class	Streams ≤10 Feet Wide	Streams >10 Feet Wide	Streams ≤10 Feet Wide	Streams >10 Feet Wide	Streams ≤10 Feet Wide	Streams >10 Feet Wide	Streams ≤10 Feet Wide	Streams >10 Feet Wide	Total RMZ Width in Feet
I	50'	50’	30’	50’	54'	34’	66'	66’	200'
II	50'	50’	30’	50’	34	20	56'	50’	170'
III	50'	--	30’	--	14'	--	46'	--	140'

Table 7. Eastside RMZs for Types S and F Streams in High Elevation Zones (thinning from below) Under Alternative 2 for Streams ≤15 Feet and >15 Feet Wide

	Type of Harvest							
	Core Zone Width in Feet (No Harvest)		Inner Zone Width in Feet (Thinning from Below)		Outer Zone Width in Feet (Intensive Harvest with Leave Trees)		Total RMZ Width in Feet	
Site Class	Streams ≤15 Feet Wide	Streams >15 Feet Wide	Streams ≤15 Feet Wide	Streams >15 Feet Wide	Streams ≤15 Feet Wide	Streams >15 Feet Wide	Streams ≤15 Feet Wide	Streams >15 Feet Wide
I	30'	30'	45	70	55	30	130	130
II	30'	30'	45	70	35	10	110	110
III	30'	30'	45	70	15	0	90	100
IV	30'	30'	45	70	0	0	75	100
V	30'	30'	45	70	0	0	75	100

Table 8. Eastside RMZs for Types S and F Streams in Ponderosa Pine and Mixed Conifer Zones (thinning) Under Alternative 2 for Streams ≤15 Feet and >15 Feet Wide

	Type of Harvest							
	Core Zone Width in Feet (No Harvest)		Inner Zone Width in Feet (Thinning)		Outer Zone Width in Feet (Intensive Harvest with Leave Trees)		Total RMZ width in feet	
Site Class	Streams ≤15 Feet Wide	Streams >15 Feet Wide	Streams ≤15 Feet Wide	Streams >15 Feet Wide	Streams ≤15 Feet Wide	Streams >15 Feet Wide	Streams ≤15 Feet Wide	Streams >15 Feet Wide
I	30'	30'	45	70	55	30	130	130
II	30'	30'	45	70	35	10	110	110
III	30'	30'	45	70	15	0	90	100
IV	30'	30'	45	70	0	0	75	100
V	30'	30'	45	70	0	0	75	100

Table 9. Eastside RMZs for Type S and F Streams in Ponderosa Pine and Mixed Conifer Zones (thinning) and High Elevation Zone (thinning from below) on Streams ≤15 Feet Wide and >15 Feet Wide that Fall Within Bull Trout Overlay

	Type of Harvest									
	Core Zone Width in Feet (No Harvest)		Inner Zone Width in Feet (leave all available shade[1/])		Inner Zone Width in Feet (Thinning or, for High Elevation, Thinning from Below)		Outer Zone Width in Feet (Intensive Harvest with Leave Trees)		Total RMZ Width in Feet	
Site Class	Streams ≤15 Feet Wide	Streams >15 Feet Wide	≤15 ft	>15 ft	≤15 ft	>15 ft	Streams ≤15 Feet Wide	Streams >15 Feet Wide	Streams ≤15 Feet Wide	Streams >15 Feet Wide
I	30'	30'	45	45	0	25	55	30	130	130
II	30'	30'	45	45	0	25	35	10	110	110
III	30'	30'	45	45	0	25	15	0	90	100
IV	30'	30'	45	45	0	25	0	0	75	100
V	30'	30'	45	45	0	25	0	0	75	100

[1/] The inner zone that falls within the first 75 feet of the bankfull width or CMZ that intercepts the bull trout overlay was separated from the rest of the inner zone and all other inner zone area under Alternative 2 for the east side. This is a way to quantify how much area would need extra consideration (under the provision that all available shade must be left) which exceeds the baseline treatment and may result in an increase of trees left in the inner zone.

2.4.5 Assumptions for Type N Streams – West Side

- For 50 percent of all N_p streams a 50-foot, no-harvest buffer, measured horizontally from the bankfull width along each side was applied. It is important to note that this is the minimum no-harvest buffer that would be applied to N_p streams. The following sensitive sites are guaranteed a 50 foot no-harvest buffer even if this results in more then 50 percent of the N_p streams in the timber harvest unit receiving a 50-foot no-harvest RMZ:
  - No timber harvest within 500 feet of intersection with type F or S stream.
  - No timber harvest is permitted in an area within 50 feet of the outer perimeter of a soil zone perennially saturated from a headwall seep.

- No timber harvest is permitted in an area within 50 feet of the outer perimeter of a soil zone perennially saturated from a side-slope seep.
- No timber harvest is permitted in an area within 50 feet of a side-slope spring.
- No timber harvest is permitted within a 100-foot by 100-foot buffer patch centered on a perennial initiation point.
- No timber harvest is permitted within an alluvial fan.
- No timber harvest is permitted within a 100-foot by 100-foot buffer patch centered on the point of intersection of two or more N_p Waters.

- For all stream miles that are either Type N perennial (N_p) and not quantified under the 50-foot no-harvest RMZ, or a Type N seasonal (N_s) stream, a 30-foot equipment limitation zone (ELZ) was applied. Though the 50-foot no-harvest RMZs are in addition to the 30-foot ELZ, when both are applied, to avoid over-quantifying the riparian area presented by the GIS, only the 50-foot no-harvest RMZ was quantified and represented in Figure 1b.

2.4.6 Assumptions for Type N Streams – East Side

- For the east side within 50 ft of the bankfull width of Np streams, the landowner must identify either a partial cut or a even-age harvest strategy for each harvest unit. This in turn will determine the restrictions within the 50 ft RMZ. Approximately 70 percent of eastside timber harvest implements a partial cut strategy (personal communication, Debbie Robinson, DNR Forest Practices Staff, January, 2000). This observation is consistent with a statewide study covering 1991-1993. The remaining 30 percent of eastside timber harvest has used an even-age strategy implemented. Therefore, for modeling purposes the partial cut strategy was applied to 70 percent of the total Np streams in the sample sections and the clearcut strategy was applied to the other 30 percent of the Np streams in the sample sections.

- Under the partial cut strategy it was assumed that all Type Np streams have a 50 ft. selective harvest buffer width (this includes a 30 ft ELZ from the bankfull width). The GIS analysis distinguished this selective harvest buffer from the selective harvest buffers that were applied to Types S and F streams since the leave tree requirements differed.

- Under the clearcut strategy 50 percent of all the Np streams a 50-foot, no-harvest buffer, measured horizontally from the bankfull width along each side was applied. It is important to note that this is the minimum no-harvest buffer that would be applied to Np streams:
  - No timber harvest within 500 feet of intersection with a type S of F stream.
  - No timber harvest is permitted in an area within 50 feet of the outer perimeter of a soil zone perennially saturated from a headwall seep.
  - No timber harvest is permitted in an area within 50 feet of the outer perimeter of a soil zone perennially saturated from a side-slope seep.
  - No timber harvest is permitted in an area within 50 feet of a side-slope spring.
  - No timber harvest is permitted within a 100-foot by 100-foot buffer patch centered on a perennial initiation point.

- No timber harvest is permitted within an alluvial fan.
- No timber harvest is permitted within a 100-foot by 100-foot buffer patch centered on the point of intersection of two or more N_p Waters.

- For all stream miles that are either a Type N perennial ($_{Np}$) that were not quantified under the 50-foot selective harvest or 50-foot no-harvest RMZ or a Type N seasonal (N_s) streams a 30-foot equipment limitation zone (ELZ) was applied. Though the 50-foot no-harvest and 50-foot selective harvest RMZs are in addition to the 30 foot ELZ, when both are applied, to avoid over-quantifying the riparian area presented by the GIS, only the 50-foot no-harvest or selective RMZ was quantified.

2.5 Task 4 - Modeling RMZ Areas Protected Under Alternative 3

Alternative 3 is relatively simple to model, relying only on stream gradient to define RMZ width. The following assumptions were made to quantify acres of RMZs under Alternative 3. These are summarized in Table 10.

2.5.1 Assumptions

- All RMZs under Alternative 3 were considered no harvest areas with the understanding that entry into the RMZ is only allowed if the landowner goes through the SEPA process.
- Under this alternative, there is no differentiation between the east and west side RMZs and gradient is the only factor used to determine RMZ widths.

Table 10. RMZ Widths Used for all Stream Types (east and west side) Under Alternative 3

Stream gradient (%)	RMZ Width (ft)	Type of Harvest
0 – 20	200	No harvest [1/]
20 – 30	100	No harvest[1/]
> 30	70	No harvest[1/]

[1/] Harvest within the RMZ can take place to improve riparian function, but must go through the SEPA process first.

2.6 Task 5 – Modeling Areas Protected as Shorelines of the State

Shorelines of the state (Type 1 waters under the current typing system) are managed under the dual jurisdiction of the Forest Practices Act and the Shoreline Management Act. The Shoreline Management Act (SMA) restrictions include a 200-foot shoreline management zone (SMZ) that has harvest restrictions and is implemented and enforced at the county level. There is variation in the way the SMA is implemented county by county. As a result, on streams designated as shorelines of the state a 200-foot SMZ buffer was applied to all three alternatives, which includes all Type 1 water bodies under Alternative 1, all Type S streams under Alternative 2, and all Type 1 streams regardless of gradient class under Alternative 3. In all three scenarios, if an RMZ is less than the SMZ, the additional area outside the RMZ that falls within an SMZ was categorized as such. Under Alternative 1, for example, Type 1 streams that have an RMZ of 75 feet are also managed as an SMZ and have an additional management zone of 125 feet outside the RMZ identified as SMZ. On the other hand, Type 1 streams under Alternative 3 that fall into the 0-20 percent gradient have a 200-foot RMZ already applied and therefore, a separate SMZ is not identified. Figures 1a and 2a quantify the SMZ area that extend beyond the designated RMZs under each alternative only.

2.7 Task 6 – Expressing RMZ Modeled Areas by Fish-bearing and Nonfish-bearing Streams

The fact that each alternative used a different water typing system created difficulties in making straightforward comparisons between modeled outcomes for RMZ areas. Each alternative's water typing system drives the process by which streams are afforded protection. It was not feasible to develop a GIS that provided crossover between all three water types for the RMZ modeling exercise. However, it was possible to create this crucial link between the three alternatives in terms of the linear distance of each stream type (see Appendix C for comparisons).

Because the final outcomes are presented in terms of protection afforded fish-bearing (S and F) waters and nonfish-bearing (N_p and N_s) waters according to Alternative 2's definitions, it was necessary to determine the distribution of Alternative 3's water types (which are based on gradient only) in terms of Alternative 2's. This was done in the Water Type section and it was necessary to assume that the same proportion exists in order to split up the RMZ areas between Type F/S waters and Type N_p and N_s waters.

For example:

> Under Alternative 3 there were 219 miles of waters with gradients <20 percent within the westside sampled sections. In terms of Alternative 2's water typing system, of these, 40 percent were Type F or S waters,
>
> 0 percent were Type N_p waters and 60 percent were N_s waters.

As part of the GIS RMZ modeling exercise, under Alternative 3, the total area that fell into a "no harvest RMZ" for waters with gradients <20 percent was 10,644 acres. So, it was assumed that of this total area, 40 percent (or 4,258 acres) was associated with fish-bearing waters (Type F and S), 0 percent with N_p streams, and 60 percent (or 6,386 acres) with N_s streams.

2.7.1 Modeling RMZ Areas for Non-Fish Bearing Waters (N_p & N_s)

Protection for nonfish-bearing waters was modeled using the following rules.

2.7.1.1 Alternative 1

No protection was provided for nonfish-bearing waters under Alternative 1, though it is recognized that Type 4 waters in some site-specific situations may have a 25 foot buffer applied.

2.7.1.2 Alternative 2

1. The total length of N_p and N_s streams was determined (See Stream Typing Section)
2. For **westside Type N_p streams**, 50 percent of the total length was given a 50-foot no harvest RMZ and 50 percent was given a 30-foot ELZ RMZ (equipment limitation zone).
3. For **westside Type N_s streams**, the entire length was given a 30-foot ELZ RMZ.
4. For **eastside Type N_p streams**, 70 percent of the total length was given a 50-foot partial cut RMZ and 70 percent of the remaining 30 percent was given a 50-foot no harvest RMZ.
5. For **eastside Type N_s streams**, the entire length was given a 30-foot ELZ RMZ.

Potential problems with this process include:

- Not accounting for overlap between Type N_s/N_p RMZs and Type S/F RMZ
- Not accounting for overlap between multiple Type N_s and N_p RMZs

2.7.1.3 Alternative 3

RMZs are not assigned according to fish-bearing or nonfish-bearing status of waters under Alternative 3. Rather, they are assigned based on the geomorphic function of different stream types (see Appendix C). However, in an effort to provide a meaningful comparison between the amount of protection afforded under each alternative, RMZ protection under Alternative 3 was expressed in terms of F/S waters, N_s waters, and N_p waters. This was done by taking the total area assigned a no harvest RMZ for each of Alternative 3's water types (based on slope class: <20 percent, 20 to 30 percent, >30 percent) and distributing the areas based on the proportion of <20 percent streams that were F/S, N_p and N_s waters.

2.8 Results

- Figures 1 and 2 present the summation of modeled RMZ areas (in acres) in the sample sections for all stream types and for each alternative. The histograms quantify the number of acres of the different management activities allowed within the RMZ (or its zones).

3. Equivalent Buffer Area Index (EBAI) Methodology for LWD

3.1 Introduction

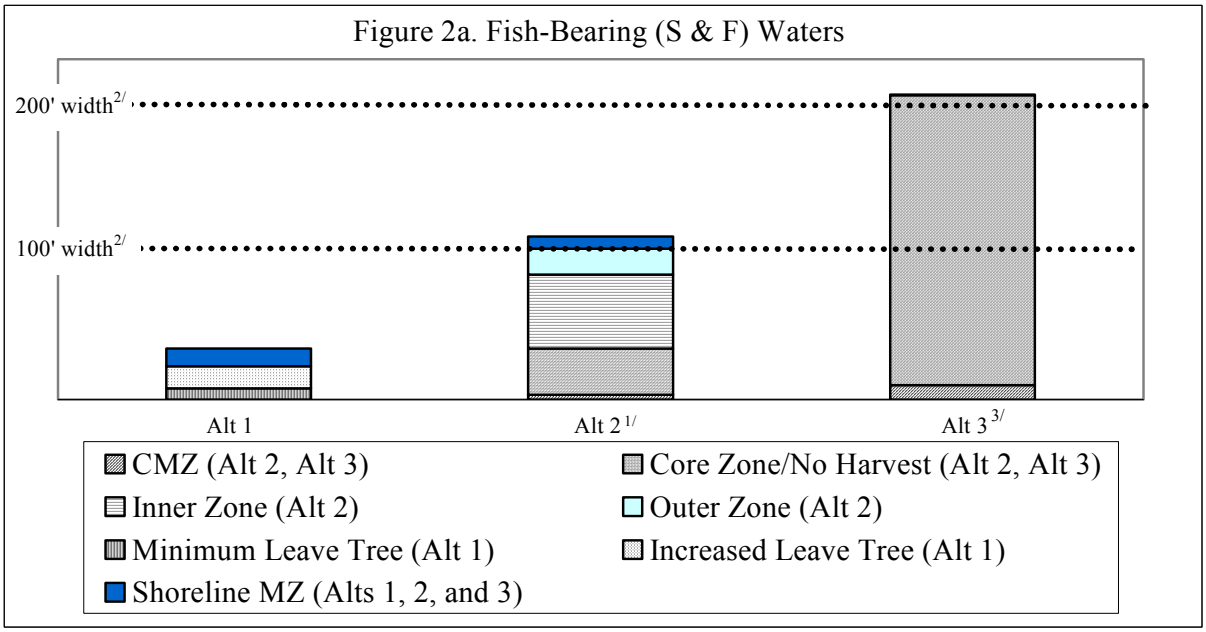
The equivalent buffer area index (EBAI) was devised by Foster Wheeler Environmental as a tool for assessing risk for streams in relation to management activities. The EBAI concept is used to evaluate the contribution of large woody debris (LWD) from proposed or existing riparian buffers.

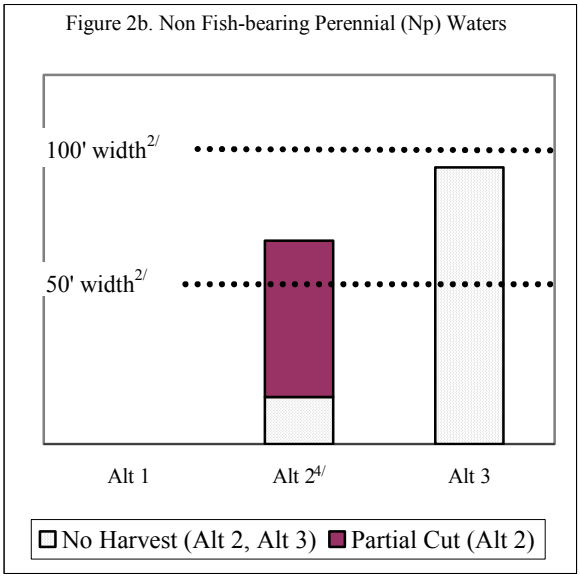
It was necessary to develop the LWD EBAI because studies in the literature typically, but not exclusively, evaluate buffer widths based on "no harvest," or preservation of mature forest with no disturbance. New management strategies include riparian areas that are divided into zones allowing different levels of timber harvest related activities and thus are not directly comparable to the buffers in the alternatives. Similarly, existing buffer strips in a given watershed may be a mixture of widths and activities, as a result of multiple jurisdictions, or Forest Practices Rules that have changed over time.

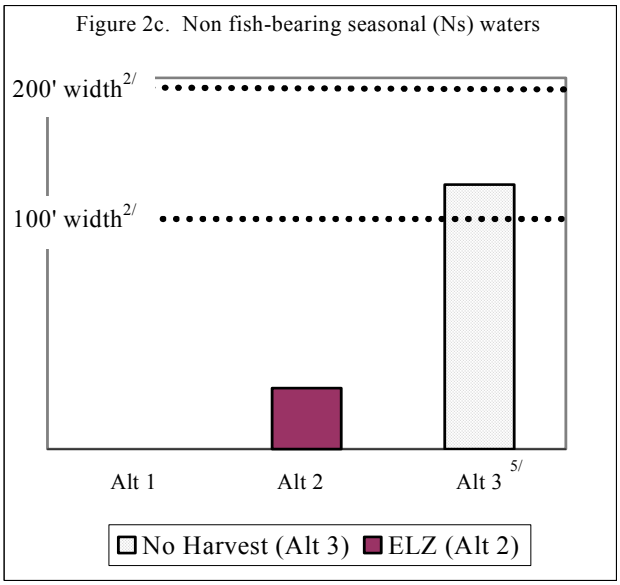
The EBAI provides a structure to take into account the management activities within the buffer zone. It combines the impacts of activities within the riparian management zones (RMZ) to compare the potential to recruit LWD by alternative.

The EBAI for large woody debris (LWD) recruitment potential is a quantitative measure that compares the potential of a riparian area to provide woody debris to streams originating from tree mortality, windthrow, and bank undercutting (which are mainly a function of slope distance from the stream channel in relationship to tree height). The value was determined for each alternative based upon a Recruitment Potential Index (RPI) coefficient. The coefficient was then applied to the number of stream miles in which the RPI was applicable. The RPI coefficient was determined for

Figure 2. Total Riparian Area Protection for Eastside Waters by Alternative and Harvest Prescription
(Note: Histograms have been standardized by estimating total acreage in each protection category and then converting it back to the average RMZ width required to cover that acreage.)







1/ The All Effective Shade requirement for bull trout may provide greater protection to 2% of Alt 2's inner zone RMZ.
2/ Standardized 50', 100' and 200' buffers were applied to all stream miles, to facilitate comparison among alternatives.
3/ Alt 3 exceeds the 200-foot standard in this figure because most fish-bearing streams receive a 200-foot RMZ, plus the CMZ acreages along some fish-bearing streams add additional acreage.
4/ For eastside Np streams, 70% of the total length of stream was given a 50-foot partial cut RMZ, and 70% of the remaining 30% was given a 50-foot no-harvest RMZ (see Section 2.7.1).
5/ A large proportion of non-fish-bearing seasonal streams were 0-20% gradient under Alt 3 and therefore receive a 200-foot RMZ. This accounts for Alt 3 RMZ acreage exceeding the 100-foot buffer standard in this figure.

each stream typing based upon different silvicultural prescriptions applied in the RMZ. There are a total of six steps that are needed to develop the RPI coefficient and run the LWD EBAI over the landscape. Each step is described below including rationale, assumptions, and outcome. This is followed by "Results," which present the calculated LWD EBAI values for each of the cases evaluated.

3.2 Step 1: Develop a "representative riparian stand"

3.2.1 Rationale

Identification of a representative riparian stand is critical to running the model. Without a quantitative description of a stand of trees, there is no way to compare the different riparian silvicultural prescriptions applied to the RMZs by alternative. In order to model a stand, it is necessary to identify the number of trees per acre grouped by diameter class.

In the following tables under Step 1 and Step 2 (Tables 13 through 28), stand data are presented as trees per acre (TPA) within fixed distance bands. These bands extend from the bankfull width out to the site potential tree height of the site class for the land adjacent to the stream. For example, the RMZ of a westside Site Class II stand is divided into distance bands of 0-50 feet, 50-80 feet, 80-100 feet, and 100-170 feet, and the RMZ of an eastside Site Class II stand is divided into bands of 0-30 feet, 30-75 feet, 75-100 feet, and 100-110 feet. The fixed distance bands are an attempt to facilitate comparison among the alternatives, rather than trying to compare the varying zone widths under Alternative 2 (Core, Inner, and Outer Zones) to the varying RMZ widths under Alternative 1 and 3. The use of fixed distance bands accounts for the varying widths of the Inner and Outer Zones under different scenarios, and captures the difference between the management of these zones and the management under Alternatives 1 and 3. This will allow direct comparison of the results from each Alternative.

Where two different silvicultural prescriptions (e.g., Alternative 2 Inner and Outer Zones; also, inside and outside the RMZ for Alternatives 1 and 3) result in varying stand densities within one distance band, trees per acre is calculated based on the proportion of each prescription within that band. For example, under Alternative 2, Option 1, the Inner Zone of the RMZ for a stream greater than 10 feet wide in a westside Site Class II stand is 78 feet wide, extending from 50 to 128 feet from the CMZ. Of the distance bands identified above, Band 4 (100-170 feet) overlaps both the Inner Zone (from 100 to 128 feet) and the Outer Zone (from 128 to 170 feet). Under Option 1, 57 TPA must be left within the Inner Zone, and 20 TPA within the Outer Zone. Thus, the stand density within the 70-foot-wide Band 4 equals:

$$\left(57\,\text{TPA}\times\frac{28'}{70'}\right)+\left(20\,\text{TPA}\times\frac{42'}{70'}\right),\ \text{or } 34.8\ \text{TPA}.$$

To further facilitate comparisons among alternatives, stacked histograms have also been developed (Figures 3 through 10c). These histograms display trees per acre (divided into size classes) within the RMZ, from the bankfull width out to the outer edge of the site potential tree height of the site class being presented, in increments of 20 feet.

3.2.2 Sensitivity Analysis

The composition of riparian stands varies considerably across the landscape, thus an assessment of the effects of timber harvest is by necessity largely site-specific. However, a meaningful comparison of the effects of timber harvest under the different alternatives is possible only if the different regulations are applied to the same stand. No single stand can capture the range of variability which occurs on the natural landscape, nor is it feasible to analyze the impacts of each alternative on every possible stand, or even several stands. With regard to LWD recruitment, however, the effects of implementing the different alternatives appear to exhibit little or no variability when applied to stands with varying site index values. In the process of choosing stands for modeling the impacts of the alternatives, a sensitivity analysis was conducted to determine whether stands with different site index values showed significant differences in how they were affected by each alternative. On the west side, EBAI Recruitment Potential Index (RPI) coefficient values were calculated for six different Site II and Site III stands, with 100-year site indices ranging from 180 to 130 (see Sections 3.4, 3.5, and 3.6 for development of RPI). In most cases, the RPI value for a particular alternative was the same or nearly the same throughout the range of site indices (Table 11). On the east side, a similar sensitivity analysis was conducted on three Mixed Conifer stands and two Ponderosa Pine stands. Because the Mixed Conifer stand data were drawn from actual sites rather than normalized yield tables, the resulting RPI values showed more variability than those for ponderosa pine or westside Douglas-fir, particularly for Alternative 1 (Table 12). The results for Alternatives 2 and 3 were very similar for the different stands, however, confirming the value of using a single stand for displaying the impacts of the alternatives. It is also worth noting that EBAI RPI values exhibited similar trends across the different alternatives, when key piece LWD was analyzed instead of functional LWD.

3.2.3 Assumptions

- It is assumed that the riparian stand developed is adjacent to a stream's bankfull width without a channel migration zone (CMZ).
- The density of trees and size distribution was based upon a "typical" 40- to 60-year old stand on the west side, and a "typical" 80- to 100-year old stand on the east side. In western Washington, outside of National Forests, forests are generally harvested by age 50, and many stands are being harvested at even younger ages (Bolsinger et al. 1997). In eastern Washington, soils and climate are less favorable for tree growth; this results in lower overall cutting rates (Bolsinger et al. 1997). Based on these facts, we assumed for the purpose of this analysis that most stands on private lands would be harvested between the ages of 40 and 60 years on the west side and between the ages of 80 and 100 years on the east side.
- For the west side, the representative stand was drawn from McArdle (1949), because stands used in the creation of the Douglas-fir yield tables in this document represent data drawn from stands from wide variety of sites over a large area (mostly western Washington, but ranging throughout the area west of the Cascade Range, from southern British Columbia to southern Oregon).

Table 11. Sensitivity Analysis of Total Cumulative Percent of Recruitable Trees[1/] per 1,000 Feet of Stream Following Harvest Under Each Alternative, for Westside Douglas-fir Stands of Different Site Classes (stand data from McArdle, 1949)

Alternative	Stream Type	Stream Width (feet)	Site Class					
			II High	II Mid	II Low	III High	III Mid	III Low
1	1	44’	22%	44%	56%	0%[2/]	0%[2/]	0%[2/]
(40’ RMZ)	2	31’	7%	9%	12%	24%	48%	62%
	3	15’	51%	55%	56%	62%	62%	62%
	4/5	5’	0%[3/]	0%[3/]	0%[3/]	0%[3/]	0%[3/]	0%[3/]
2 – Option 1	S&F	44’	96%	96%	96%	0%	0%	0%
	S&F	31’	96%	96%	96%	93%	93%	93%
	S&F	15’	96%	96%	96%	93%	93%	93%
	S&F	5’	87%	89%	91%	91%	93%	93%
2 – Option 2	S&F	44’	94%	94%	94%	NA[4/]	NA[4/]	NA[4/]
	S&F	31’	94%	94%	94%	NA[4/]	NA[4/]	NA[4/]
	S&F	15’	94%	94%	95%	NA[4/]	NA[4/]	NA[4/]
	S&F	5’	92%	92%	94%	95%	96%	97%
2	N_p	5’	35%[5/]	35%[5/]	35%[5/]	39%[5/]	39%[5/]	39%[5/]
3	<20%	44’	100%	100%	100%	0%[2/]	0%[2/]	0%[2/]
	<20%	5’	100%	100%	100%	100%	100%	100%
	20-30%	44’	94%	94%	94%	0%[2/]	0%[2/]	0%[2/]
	20-30%	5’	94%	94%	94%	97%	97%	97%
	> 30%	44’	81%	81%	81%	0%[2/]	0%[2/]	0%[2/]
	> 30%	5’	81%	81%	81%	88%	88%	88%

[1/] Cumulative percent is based on comparing the number of trees left in the RMZ to the number of trees in the same area prior to implementing the prescriptions. However, the relationship between buffer width and potential LWD inputs from the adjacent riparian zone are non-linear with a greater percentage occurring closer to the stream. Therefore, cumulative percent of recruitable trees is a result of recruitment potential from different portions of the RMZ.

[2/] No trees in the original stand meet the size requirement for functional wood on a 44-foot stream.

[3/] Timber harvest is allowed up to the stream bank.

[4/] Alternative 2, Option 2 is not permitted along streams greater than 10 feet wide within Site Class III stands.

[5/] Alternative 2 harvest restrictions result in a higher level of protection than is shown by these numbers, but this protection occurs only along half the length of the stream. Therefore the percent values calculated by the EBAI were multiplied by 0.5, to produce the values seen in this table.

Table 12. Sensitivity analysis of total cumulative percent of recruitable trees[1/] per 1,000 feet of stream following harvest under each alternative, for eastside Mixed Conifer (mixed) and Ponderosa Pine (PIPO) stands of different Site Classes.

	Stream	Stream	Even-aged (0 TPA)					Partial Cut (21 TPA)				
Alternative	Type	Width	Mixed II	Mixed II[2/]	Mixed IV	PIPO II	PIPO IV	Mixed II	Mixed II[2/]	Mixed IV	PIPO II	PIPO IV
1[3/]	1	45	17%	12%	71%	40%	24%	12%	11%	67%	37%	22%
	2	25	32%	23%	74%	47%	42%	33%	24%	73%	47%	43%
	3	12	41%	36%	75%	51%	52%	41%	35%	74%	50%	51%
	4/5	5	41%	36%	75%	51%	52%	19%	14%	31%	20%	24%
2	S&F	45	71%	70%	89%	71%	81%	71%	70%	89%	71%	81%
Not within	S&F	25	76%	74%	86%	76%	85%	76%	74%	86%	76%	85%
Bull Trout	S&F	12	73%	73%	84%	74%	82%	74%	73%	84%	74%	82%
Habitat overlay[4/]	S&F	5	73%	73%	84%	74%	82%	74%	73%	84%	74%	82%
2	S&F	45	97%	96%	99%	97%	98%	97%	96%	99%	97%	98%
Within Bull	S&F	25	97%	97%	99%	97%	99%	97%	97%	99%	97%	99%
Trout Habitat	S&F	12	96%	96%	98%	96%	98%	96%	96%	98%	96%	98%
overlay[4/]	S&F	5	96%	96%	98%	96%	98%	96%	96%	98%	96%	98%
2	N_p	5	55%[5/]	55%[5/]	59%[5/]	55%[5/]	59%[5/]	27%	27%	32%	24%	36%
3	<20%	45	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	<20%	5	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	20-30%	45	99%	99%	100%	99%	100%	99%	99%	100%	99%	100%
	20-30%	5	99%	99%	100%	99%	100%	99%	99%	100%	99%	100%
	>30%	45	93%	93%	95%	93%	95%	93%	93%	95%	93%	95%
	>30%	5	93%	93%	95%	93%	95%	93%	93%	96%	93%	95%

[1/] Cumulative percent is based on comparing the number of trees left in the RMZ to the number of trees in the same area prior to implementing the prescriptions. However, the relationship between buffer width and potential LWD inputs from the adjacent riparian zone are non-linear with a greater percentage occurring closer to the stream. Therefore, cumulative percent of recruitable trees is a result of recruitment potential from different portions of the RMZ.

[2/] Data were available for two eastside Mixed Conifer Site Class II stands. One was fully cruised, the other (presented in this column) was sampled as a 1/5-acre plot.

[3/] For even-aged harvest, an average RMZ width of 50 feet was assumed; for partial cut, an average RMZ width of 40 feet was assumed.

[4/] Implementation of the shade rule within the bull trout habitat zone was assumed to require no harvest within 75 feet of the stream's bankfull width. In actual practice, some trees may likely be removed from this zone without diminishing effective shade; these values indicate the upper end of the range of protection which may be afforded to S and F type streams within the bull trout zone under Alternative 2.

[5/] Alternative 2 harvest restrictions result in a higher level of protection than is shown by these numbers, but this protection occurs only along 70% of the length of the stream. Therefore the percent values calculated by the EBAI were multiplied by 0.7, to produce the values seen in this table.

- Stand tables in McArdle (1949) represent 100 percent stocking of Douglas-fir. To account for the presence of hardwoods, rocky outcrops, or natural openings, TPA values within each size class were multiplied by 0.8, to create stands of 80 percent stocking. It is worth noting that stocking levels had a negligible impact on any given stand's potential to meet the basal area requirements of Desired Future Conditions, when modeled with ORGANON. This is because the lower density of an 80 percent stocked stand results in less competition among individual trees. Thus, even though a stand with 80 percent stocking has fewer trees, these trees attain a larger size at 140 years than they would in a more crowded stand. The resulting basal area per acre is approximately the same in both fully stocked and 80 percent stocked stands.

- Based on the above, a low-quality Site Class II (100-year site index = 160; 50-year site index = 119) stand with 80 percent stocking was chosen for modeling on the west side. Several rationales drove this choice: 1) Site Class II and III are most common across the landscape; 2) in the representative sample of state sections, Site Class II and III were evenly represented; 3) sensitivity analysis (see below) of stands with varying site indices found very little variation in each alternative's impacts on sites in different Site Classes; and 4) under Alternative 2, Option 2 is not permitted for streams greater than 10 feet wide within Site Class III stands, thus the only way to assess the impacts of Option 1 and Option 2 on LWD recruitment potential in both small and large fish-bearing streams is to use a Site Class II stand.

- The stand of trees used for modeling from the east side was a fully cruised stand from the Mixed Conifer zone in eastern Washington. As described above, sensitivity analysis detected only minimal differences among several stands; this stand fell near the middle of the range of variability.

3.3 Step 2: Apply silvicultural prescriptions for RMZs by alternative

3.3.1 Rationale

Based on the RMZ guidelines defined for each alternative, specific silvicultural prescriptions were applied to eastside and westside representative stands. The number and density of trees remaining after harvest (leave trees) could then be compared, as a quantitative index of the relative change due to different harvest prescriptions. These leave trees were quantified based on the proportion remaining in each size class (based on dbh) compared to what had existed in the original stand. Harvesting the east side and west side "representative" stands facilitates comparison of the different management strategies. Westside and eastside assumptions and outcomes are presented separately.

3.3.2 Westside RMZs

3.3.2.1 General Assumptions

- It is assumed that the riparian stand developed is adjacent to the bankfull width of a stream that does not have a channel migration zone (CMZ).
- Model a representative 50-year-old Site Class II stand (site index = 119)
- Trees are distributed evenly through all zones (that is, on a per-acre basis, trees in the Core Zone have the same distribution of diameter and species as trees in the Outer Zone)
- No placement strategy that was agreed to by the landowner and the State exists
- Douglas-fir is the preferred species for leave trees

3.3.3 Outcome

Table 13. Trees per acre (TPA[1/]) within each distance band[2/] of the RMZ for the westside riparian stand (Site Class = II, 50-year site index = 119) used for modeling the effects of the different alternatives on LWD availability.

DBH Range	TPA in Band 1 (0 - 50')	TPA in Band 2 (50 - 80')	TPA in Band 3 (80 - 100')	TPA in Band 4 (100 - 170')
6" - 12"	160	160	160	160
12" - 18"	62	62	62	62
18" - 24"	11	11	11	11
24" - 30"	0	0	0	0
>30"	0	0	0	0
Total TPA	233	233	233	233
Total BA/acre	152	152	152	152

1/ To translate Trees Per Acre into Trees Per 1000 Feet of Stream, multiply the TPA value by 1.15 for Zone 1, by 0.69 for Zone 2, by 0.50 for Zone 3, or by 1.61 for Zone 4.

2/ To facilitate comparison between alternatives, stand data are presented as trees per acre (TPA) within fixed-width distance bands between the stream's bankfull width and the site potential tree height (see Section 3.0, Step 1, Rationale, for a discussion of distance bands).

Figure 3. Westside Riparian Stand (Site Class = II) Used for Modeling Purposes Presented by Size Class in Trees per Acre (TPA[1/]) within RMZ Presented from Bankfull Width out to the Outer Edge of the 100-year Site Potential Tree Height in Increments of 20 Feet

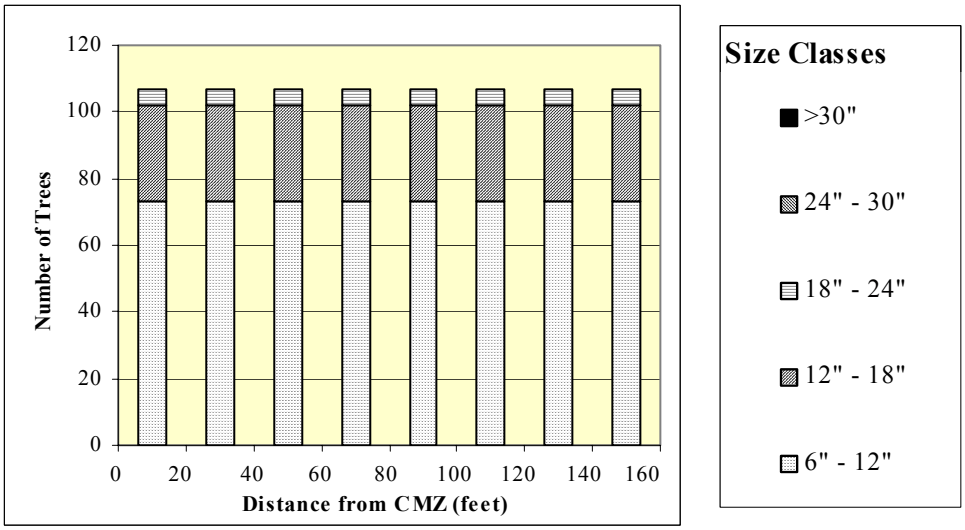


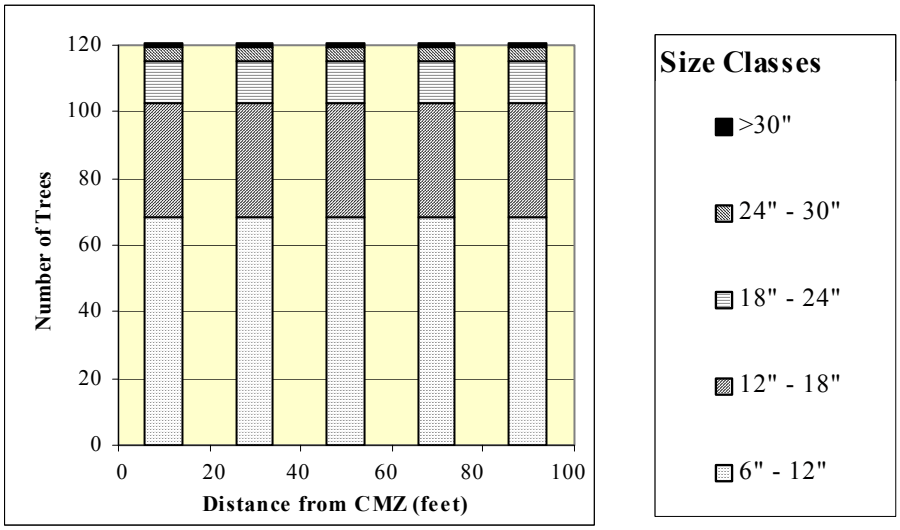
Table 14. Trees per Acre (TPA[1/]) within Each Distance Band[2/] of the RMZ for the Eastside Riparian Stand (Site Class = II, 50-year Site Index = 105) Used for Modeling the Effects of the Different Alternatives on LWD Availability

DBH Range	TPA in Band 1 (0 - 30')	TPA in Band 2 (30 - 75')	TPA in Band 3 (75 - 100')	TPA in Band 4 (100 - 110')
6" - 12"	149	149	149	149
12" - 18"	75	75	75	75
18" - 24"	27	27	27	27
24" - 30"	9	9	9	9
>30"	3	3	3	3
Total TPA	263	263	263	263
Total BA/acre	246	246	246	246

1/ To translate Trees Per Acre into Trees Per 1000 Feet of Stream, multiply the TPA value by 0.69 for Zone 1, by 1.03 for Zone 2, by 0.57 for Zone 3, or by 0.23 for Zone 4.

2/ To facilitate comparison between alternatives, stand data are presented as trees per acre (TPA) within fixed-width distance bands between the stream's bankfull width and the site potential tree height (see Section 3.0, Step 1, Rationale, for a discussion of distance bands).

Figure 4. Eastside Riparian Stand (Site Class = II) Used for Modeling Purposes Presented by Size Class in Trees per Acre (TPA[1/]) within RMZ Presented from Bankfull Width out to the Outer Edge of the 100-year Site Potential Tree Height in Increments of 20 Feet



- Riparian Leave Trees are defined as conifers greater than or equal to 12 inches dbh
- The shade rule was not taken into account when modeling the different alternatives. This provides a baseline of the trees required to be maintained in the RMZ for comparative purposes between all three alternatives. It can be assumed that where the shade rule is applied, additional trees will likely be left.

3.3.3.1 Assumptions for Alternative 1

- Model prescriptions for a stream with a cobble-gravel substrate
- Average RMZ width is assumed to be 40 feet (based on personal communication, Sue Casey, DNR Forester, October, 1999).
- The number of trees left per 1000 feet of stream includes the 5 largest trees per acre, with a one-to-one ratio of conifer to hardwood (i.e., 2.5 of the largest conifer trees per acre, and 2.5 of the largest hardwood trees per acre); these trees are assumed to meet the requirements for Green Recruitment Trees and Wildlife Leave Trees. Because the stand used for modeling does not include a hardwood component, the largest 2.5 hardwood trees per acre are assumed to fall within the 12-inch size class. Although this may underestimate the size of the largest hardwoods, the overall distribution of tree sizes within the stand, and hence the availability of functional LWD, is essentially the same whether hardwoods are modeled as present or not.
- Assume a 40-foot partial cut buffer adjacent to the stream; clearcut harvest is assumed outside of the RMZ, but within the SPTH.
- The shade rule is not implemented in this scenario to present the maximum harvest allowed within the RMZ under Alternative 1. Implementation of the shade rule would likely require the retention of more trees in the RMZ, resulting in an increase in TPA and BA/acre.

Specific prescriptions for Type 1 & 2 Streams:

- For modeling purposes it was assumed that all Type 1 and Type 2 streams are less than 75 feet wide.
- The 5 largest trees per acre are counted toward the requirement of 100 leave trees per 1,000 feet of stream length (for a 40-foot RMZ, 5 trees per acre equates to 4.59 trees per 1,000 feet)
- Per WAC 222-30-020, the distribution of size class and species (i.e., ratio of conifers to hardwoods) of leave trees must be representative of the original stand. As described in Forest Practices Illustrated (DNR 1997) and confirmed by DNR foresters (personal communication, Ben Cleveland, DNR, January 2000), the stand was grouped into three size classes, <6 inches, 6-12 inches, and >12 inches dbh. After modeling timber harvest, the relative proportion of leave trees in these size classes matched the relative proportion of trees in the original stand within those classes. Although the stand used for modeling did not include a hardwood component, the results of modeling Alternative 1 in the representative stand were very similar to those for a stand composed of 50 percent Douglas-fir and 50 percent red alder.
- The stand tables presented in this document only show trees larger than 6 inches dbh. However, the yield tables in McArdle (1949) give TPA values for trees as small as 2 inches dbh. These trees were taken into account in determining the proportion of leave trees in each size category.

Consequently, there are 13 leave TPA (or 15 leave trees per thousand feet of stream) <6 inches in the representative stand that are not reported in the tables and figures depicting the results of the analysis..

- Within each size class, the smallest trees are selected as leave trees (e.g., in the 6 to12-inch class, most leave trees will be 6 to 8 inches dbh based on the representative stand used for modeling). This assumption was confirmed by DNR enforcement personal as the standard practice in the field within westside RMZs along Type 1 and 2 streams (personal communication, Ben Cleveland, DNR, January 2000).

- For modeling purposes it is assumed that all trees left in the RMZ are alive. However, it is important to note that the WAC 222-30-020 states that a minimum of fifty percent of the trees that are left in the RMZ must be live and undamaged on completion of the harvest, implying that up to fifty percent of leave trees may actually be snags or damaged trees. Therefore, this assumption may result in an overestimation of the number of viable trees left in the RMZ.

Specific prescriptions for Type 3 streams greater than 5 feet wide:

- The 5 largest trees per acre will be counted toward the requirement of 75 leave trees per 1,000 feet of stream length, as well as for Green Recruitment Tree and Wildlife Leave Tree requirements.

- Leave trees will be greater than or equal to 12 inches dbh

- Where applicable, a 2:1 ratio of conifers to hardwoods will be maintained.

3.3.3.2 Outcome for Alternative 1

Table 15 presents the tree density in trees per acre (TPA) remaining in each fixed distance band after Alternative 1 prescriptions were modeled using the westside representative stand (see Table 13) along Types 1, 2, and 3 streams.

Figures 5a and 5b display the leave tree density (in TPA) remaining in the RMZ, after harvest under Alternative 1 along Type 1, 2 and 3 streams. Data are presented in 20 foot increments from the bankfull width out to the outer edge of the site potential tree height of 170 feet (Site Class II) Each bar in the figure is segmented by size class (in dbh).

3.3.3.3 Assumptions for Alternative 2

Specific Prescriptions for Type S & F Streams:

The "Desired Future Conditions" were modeled using the ORGANON growth module built into the Riparian Aquatic Interaction Simulator (RAIS) developed by Jeff Welty at Weyerhaeuser Co. This model was used on the recommendation of Mark Hunter, fish biologist with Washington Department of Fish and Wildlife (Personal communication, October 1999). The "Desired Future Condition" (also known as the Stand Requirements) for a particular riparian stand consists of a certain basal area value (based on the stand's Site Class), which must be attained by a stand age of 140 years (see Chapter 2, Alternative 2 description). The model was designed to predict LWD input, but it also models basal area per acre over time, based on user-input values for site index, trees per acre (TPA), quadratic mean dbh (QMD), and tree height. To model future basal area values for the representative stand, TPA and QMD were calculated using the size class distribution

Table 15. Trees per Acre (TPA[1/]) Left Within the RMZ[2/] of a Westside Type 1, 2, or 3 Stream Following Harvest Under Alternative 1, Presented in Fixed-width Distance Bands[3/] from the Stream's Bankfull Width, Using a Site Class II Riparian Stand as an Example

		Post-harvest (Type 1 or 2 Stream)				Post-harvest (Type 3 Stream)			
DBH Range[4/]	Pre-harvest TPA	TPA in Band 1 (0 - 50')[5/]	TPA in Band 2 (50 - 80')	TPA in Band 3 (80 - 100')	TPA in Band 4 (100 - 170')	TPA in Band 1 (0 - 50')[5/]	TPA in Band 2 (50 - 80')	TPA in Band 3 (80 - 100')	TPA in Band 4 (100 - 170')
6" - 12"	160	51	0	0	0	7	0	0	0
12" - 18"	62	21	0	0	0	49	0	0	0
18" - 24"	11	2	0	0	0	9	0	0	0
24" - 30"	0	0	0	0	0	0	0	0	0
>30"	0	0	0	0	0	0	0	0	0
Total TPA	233	74	0	0	0	65	0	0	0
Total BA/acre	152	36	0	0	0	75	0	0	0

1/ To translate Trees Per Acre into Trees Per 1000 Feet of Stream, multiply the TPA value by 1.15 for Zone 1, by 0.69 for Zone 2, by 0.50 for Zone 3, or by 1.61 for Zone 4.

2/ The calculation of the number of trees remaining in the RMZ following harvest under this alternative does not account for the implementation of the shade rule (which may increase the numbers of leave trees remaining in the RMZ) or the fact that only 50 percent of the leave trees left in the RMZ need to be alive (which may reduce the number of trees remaining in the RMZ).

3/ To facilitate comparison between alternatives, stand data are presented as trees per acre (TPA) within fixed-width distance bands between the stream's bankfull width and the site potential tree height (see Section 3.0, Step 1, Rationale, for a discussion of distance bands).

4/ For Type 1&2 streams, Alternative 1 calls for 100 leave trees per 1000 feet of stream, with a size class distribution representative of the original stand. Leave trees are grouped into three size classes: <6 inches, 6-12 inches, and >12 inches dbh. Within the 40-foot RMZ of the stand used for modeling, 15 trees per 1,000 feet fell into the <6" dbh size class, and thus do not appear in this table. The Total TPA value in this table represents 85 trees per 1,000 feet of 40-foot wide RMZ, proportionally scaled to reflect TPA within a 50-foot distance band.

5/ The RMZ modeled for Alternative 1 is 40 feet wide, 10 feet narrower than the fixed-width band presented in this table. The TPA value for this band reflects the fact that this band contains 40 feet of RMZ and 10 feet of clearcut harvest (see Section 3.0, Step 1, under Rationale for a discussion of calculating TPA values for bands which contain varying leave tree densities).

of trees within the stand. Since RAIS calculates stand age as a function of site index and tree height, a tree height value was chosen such that stand age would be as close as possible to 50 years. RAIS allows users to model stand conditions in an inner (No-Touch) zone and an outer (Managed) zone. The Core Zone of Alternative 2 was modeled as No-Touch, and the Inner Zone was modeled as Managed.

The potential for different silvicultural prescriptions to meet the Stand Requirements was modeled using the representative stand described under Step 1. The representative stand (a Site Class II Douglas-fir stand with 80 percent stocking and a 50-year site index of 119) must meet a basal area of 275 ft^2/ac at a stand age of 140 years as defined in the Forest and Fish Report (1999), and was modeled as follows:

- for the Core Zone, current (stand age 50 years) stand conditions were entered as described above, and were projected under the No-Touch management regime;
- for the Inner Zone, TPA and QMD values were entered such that the total combined basal area of the Core Zone and the Inner Zone would meet or exceed 275 ft^2/ac at 140 years, **and** the Inner Zone would maintain at least 57 TPA following harvest;

Figure 5a. Westside Leave Trees in RMZ for Alternative 1 Presented in 20-foot Increments (measured from bankfull width out to the outer edge of the 100-year SPTH) Along Type 1and 2 Streams, Totaled by TPA (sub-divided into size class)

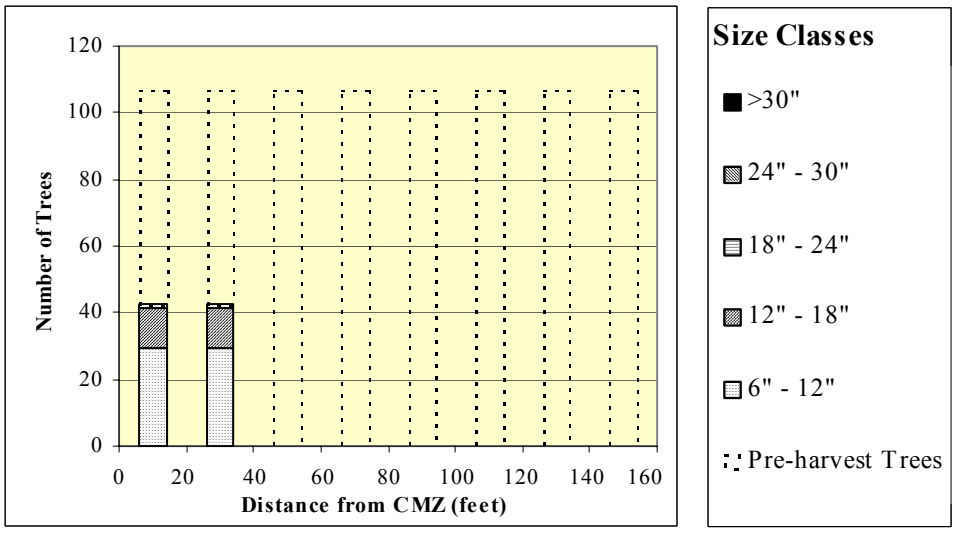
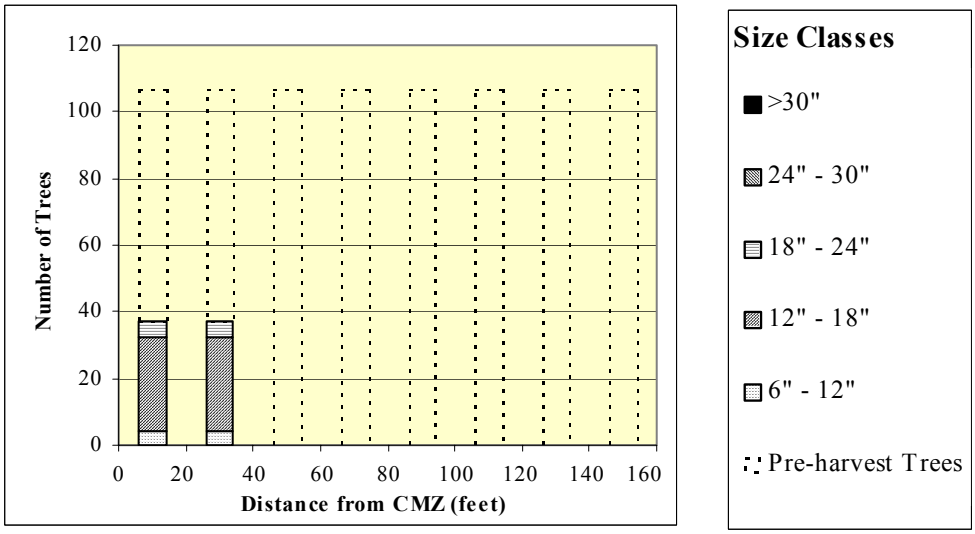


Figure 5b. Westside Leave Trees in RMZ for Alternative 1 Presented in 20-foot Increments (measured from bankfull width out to the outer edge of the SPTH) Along Type 3 Streams and Totaled by TPA (sub-divided into size class)



- Inner Zone TPA and QMD values were calculated from the tree size distribution resulting from the prescriptions dictated by the Options described below.

  Option 1(a) – streams less than or equal to 10 feet wide
  Core Zone: 50 feet wide, no harvest
  Inner Zone: 63 feet wide, thin from below: leave the 57 largest trees and enter the resulting TPA and QMD values into the RAIS model. If the resulting basal area at 140 years, combined proportionally with the 140-year basal area for the Core Zone, is less than 275 ft^2/ac, then add some of the smaller trees back in. Repeat until the resulting 140-year basal area equals or exceeds 275 ft^2/ac. NOTE: In each of the six stands included in the sensitivity analysis (see final paragraph under "Rationale" for Step 1, above), leaving the 57 largest trees per acre met the Stand Requirements, and no additional leave trees were required.
  Outer Zone: 57 feet wide, leave 20 TPA.

  Option 1(b) – streams greater than 10 feet wide
  Core Zone: 50 feet wide, no harvest
  Inner Zone: 78 feet wide, modeled as for Option 1(a)
  Outer Zone: 42 feet wide, leave 20 TPA.

  Option 2(a) – streams less than or equal to 10 feet wide
  Core Zone (floor distance): 80 feet wide, no harvest
  Inner Zone: 34 feet wide, remove all trees less than 12 inches dbh, and as many Riparian Leave Trees as will reduce the resulting 140-year basal area to a value which, when combined with the basal area of the Core Zone, is as close as possible to 275 ft^2/ac, without going below that value. Once this number of trees has been determined to meet the desired future condition basal area requirement, an additional 20 TPA were left.
  Outer Zone: 56 feet wide, leave 20 TPA. If the no-harvest restriction in the Core Zone results in the retention of enough trees to exceed a basal area (in the Core Zone and Inner Zone combined) of 275 ft^2/ac at 140 years, then fewer than 20 TPA may be retained in the Outer Zone. The amount of this deduction was determined by sequentially deleting individual trees from the Core Zone, and combining each resulting 140-year basal area value with a basal area of 0 in the Inner Zone. The number of trees that would reduce the total combined 140-year basal area to as close as possible to 275 ft^2/ac, without going below that value, determined the number of trees which may be deducted from the 20 TPA requirement (that is, if the landowner had been allowed to cut 6 TPA in the Core Zone and still attain a basal area of 275 ft^2/ac at 140 years, then they will be allowed instead to leave 14 instead of 20 TPA in the Outer Zone). No more than 10 TPA may be deducted from the Outer Zone as required under the Forest and Fish Report (1999) (i.e., no fewer than 10 TPA may be left in the Outer Zone). NOTE: For the six stands included in the sensitivity analysis, the Core Zone no-harvest requirement resulted in no "excess" basal area retention, therefore 20 TPA were retained in the Outer Zone.

Option 2(b) – streams greater than 10 feet wide
Core Zone (floor distance): 100 feet wide, no harvest
Inner Zone: 20 feet wide, modeled as for Option 2(a).
Outer Zone: 50 feet wide, modeled as for Option 2(a).

Specific Prescriptions of N_p Streams:

- 50-foot no-cut buffer adjacent to the stream's bankfull width; clearcut harvest outside of the 50-foot no-cut buffer but within one 100-year SPTH.
- This no-cut buffer was modeled for 50 percent of the total length of westside N_p streams. The remaining 50 percent was modeled as a clearcut to the stream's edge.

3.3.3.4 Outcome for Alternative 2

Tables 16 and 17 present the tree density in trees per acre (TPA) remaining in each RMZ band after Alternative 2 prescriptions were modeled using the westside representative stand (see Table 13) along Types S and F streams. Table 16 models Option 1 and Table 17 models Option 2. Table 18 presents the same information for stands along Type N_p streams that have an RMZ after implementing Alternative 2 prescriptions.

Figures 6 a, b, c, d, and e are bar graphs that displays the leave tree density (in TPA) remaining in the RMZ presented in 20 foot increments from the bankfull width out to the outer edge of the site potential tree height (site class II) after harvest along Type S, F streams ($\leq$ and > 10 feet) and N_p streams. Each bar in the figure is segmented by size class (in dbh).

Table 16. Trees per Acre (TPA[1/]) Left within the RMZ[2/] of a Westside Type S or F Stream Following Harvest Under Alternative 2 Option 1, Presented in Fixed-width Distance Bands[3/] from the Stream's Bankfull Width, Using a Site Class II Riparian Stand as an Example

		Post-harvest (Streams ≤10' Wide)				Post-harvest (Streams >10' Wide)			
DBH Range	Pre-harvest TPA	TPA in Band 1 (0 - 50')	TPA in Band 2 (50 - 80')	TPA in Band 3 (80 - 100')	TPA in Band 4 (100 - 170')	TPA in Band 1 (0 - 50')	TPA in Band 2 (50 - 80')	TPA in Band 3 (80 - 100')	TPA in Band 4 (100 - 170')
6" - 12"	160	160	0	0	0	160	0	0	0
12" - 18"	62	62	46	46	25	62	46	46	30
18" - 24"	11	11	11	11	2	11	11	11	4
24" - 30"	0	0	0	0	0	0	0	0	0
>30"	0	0	0	0	0	0	0	0	0
Total TPA	233	233	57	57	27	233	57	57	35
Total BA/acre	152	152	76	76	28	152	76	76	41

1/ To translate Trees Per Acre into Trees Per 1000 Feet of Stream, multiply the TPA value by 1.15 for Zone 1, by 0.69 for Zone 2, by 0.50 for Zone 3, or by 1.61 for Zone 4.

2/ The calculation of the number of trees remaining in the RMZ following harvest under this alternative does not account for the implementation of the shade rule (which may increase the numbers of leave trees remaining in the RMZ) or the fact that only 50 percent of the leave trees left in the RMZ need to be alive (which may reduce the number of trees remaining in the RMZ).

3/ To facilitate comparison between alternatives, stand data are presented as trees per acre (TPA) within fixed-width distance bands between the stream's bankfull width and the site potential tree height (see Section 3.0, Step 1, Rationale, for a discussion of distance bands).

Table 17. Trees per Acre (TPA[1/]) Left Within the RMZ[2/] of a Westside Type S or F Stream Following Harvest Under Alternative 2 Option 2, Presented in Fixed-width Distance Bands[3/] from the Stream's Bankfull Width, Using a Site Class II Riparian Stand as an Example

		Post-harvest (Streams ≤10' Wide)				Post-harvest (Streams >10' Wide)			
DBH Range	Pre-harvest TPA	TPA in Band 1 (0 - 50')	TPA in Band 2 (50 - 80')	TPA in Band 3 (80 - 100')	TPA in Band 4 (100 - 170')	TPA in Band 1 (0 - 50')	TPA in Band 2 (50 - 80')	TPA in Band 3 (80 - 100')	TPA in Band 4 (100 - 170')
6" - 12"	160	160	160	0	0	160	160	160	0
12" - 18"	62	62	62	29	22	62	62	62	21
18" - 24"	11	11	11	0	0	11	11	11	0
24" - 30"	0	0	0	0	0	0	0	0	0
>30"	0	0	0	0	0	0	0	0	0
Total TPA	233	233	233	29	22	233	233	233	21
Total BA/acre	152	152	152	25	19	152	152	152	18

1/ To translate Trees Per Acre into Trees Per 1000 Feet of Stream, multiply the TPA value by 1.15 for Zone 1, by 0.69 for Zone 2, by 0.50 for Zone 3, or by 1.61 for Zone 4.

2/ The calculation of the number of trees remaining in the RMZ following harvest under this alternative does not account for the implementation of the shade rule (which may increase the numbers of leave trees remaining in the RMZ) or the fact that only 50 percent of the leave trees left in the RMZ need to be alive (which may reduce the number of trees remaining in the RMZ).

3/ To facilitate comparison between alternatives, stand data are presented as trees per acre (TPA) within fixed-width distance bands between the stream's bankfull width and the site potential tree height (see Section 3.0, Step 1, Rationale, for a discussion of distance bands).

Table 18. Trees per Acre (TPA[1/]) Left Within the RMZ[2/] of a Westside Type N_p Stream Following Harvest Under Alternative 2, Presented in Fixed-width Distance Bands[3/] from the Stream's Bankfull Width, Using a Site Class II Riparian Stand as an Example

		Post-harvest			
DBH Range	Pre-harvest TPA	TPA in Band 1 (0 - 50')	TPA in Band 2 (50 - 80')	TPA in Band 3 (80 - 100')	TPA in Band 4 (100 - 170')
6" - 12"	160	160	0	0	0
12" - 18"	62	62	0	0	0
18" - 24"	11	11	0	0	0
24" - 30"	0	0	0	0	0
>30"	0	0	0	0	0
Total TPA	233	233	0	0	0
Total BA/acre	152	152	0	0	0

1/ To translate Trees Per Acre into Trees Per 1000 Feet of Stream, multiply the TPA value by 1.15 for Zone 1, by 0.69 for Zone 2, by 0.50 for Zone 3, or by 1.61 for Zone 4.

2/ The calculation of the number of trees remaining in the RMZ following harvest under this alternative does not account for the implementation of the shade rule (which may increase the numbers of leave trees remaining in the RMZ) or the fact that only 50 percent of the leave trees left in the RMZ need to be alive (which may reduce the number of trees remaining in the RMZ).

3/ To facilitate comparison between alternatives, stand data are presented as trees per acre (TPA) within fixed-width distance bands between the stream's bankfull width and the site potential tree height (see Section 3.0, Step 1, Rationale, for a discussion of distance bands).

Figure 6a. Westside Trees Remaining in RMZ Under Alternative 2 Option 1 ≤10 Feet Presented in 20-foot Increments (measured from bankfull width out to the outer edge of the 100-year SPTH) Along Types S, F Streams and Totaled by TPA (sub-divided into size class)

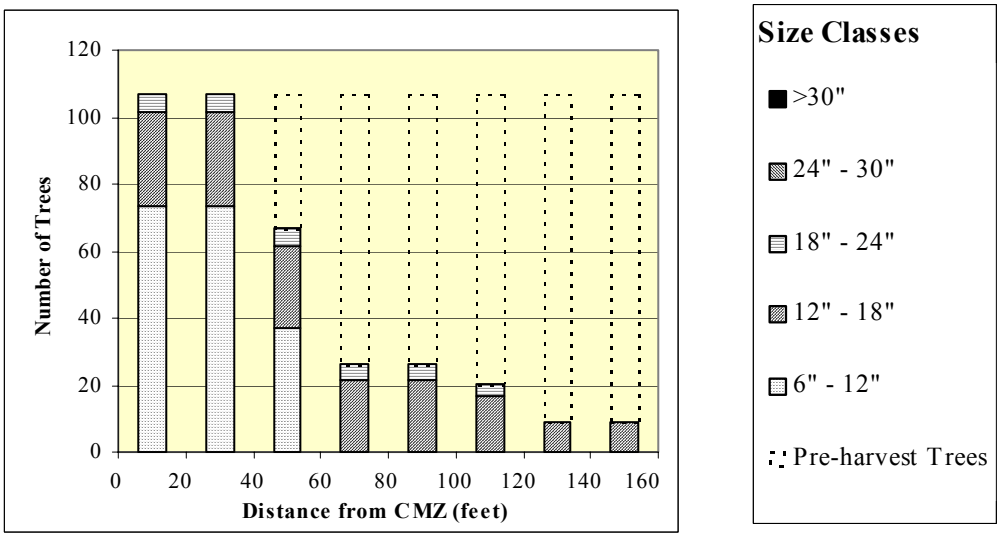


Figure 6b. Westside Trees Remaining in RMZ Under Alternative 2 Option 1 >10 Feet Presented in 20-foot Increments (measured from bankfull width out to the outer edge of the 100-year SPTH) Along Types S, F Streams and Totaled by TPA (sub-divided into size class)

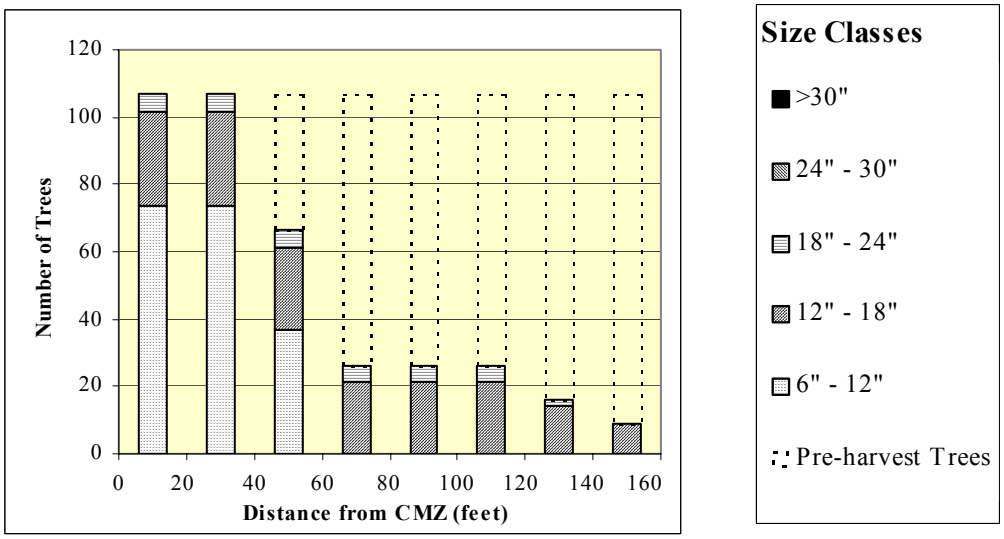


Figure 6c. Westside Trees Remaining in RMZ Under Alternative 2 Option 2 ≤10 Feet Presented in 20-foot Increments (measured from bankfull width out to the outer edge of the 100-year SPTH) Along Types S, F Streams and Totaled by TPA (sub-divided into size class)

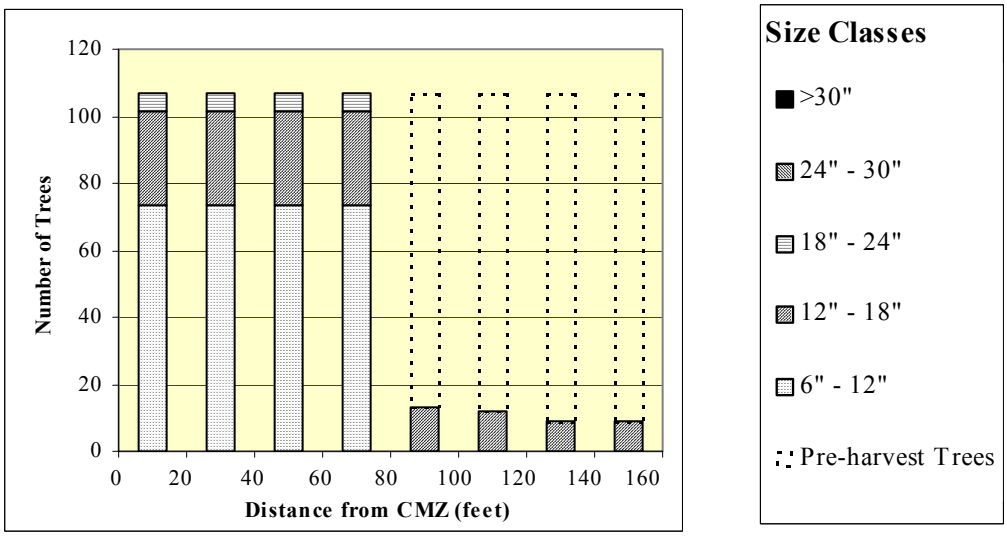


Figure 6d. Westside Trees Remaining in RMZ Under Alternative 2 Option 2 >10 Feet Presented in 20-foot Increments (measured from bankfull width out to the outer edge of the 100-year SPTH) Along Types S, F Streams and Totaled by TPA (sub-divided into size class)

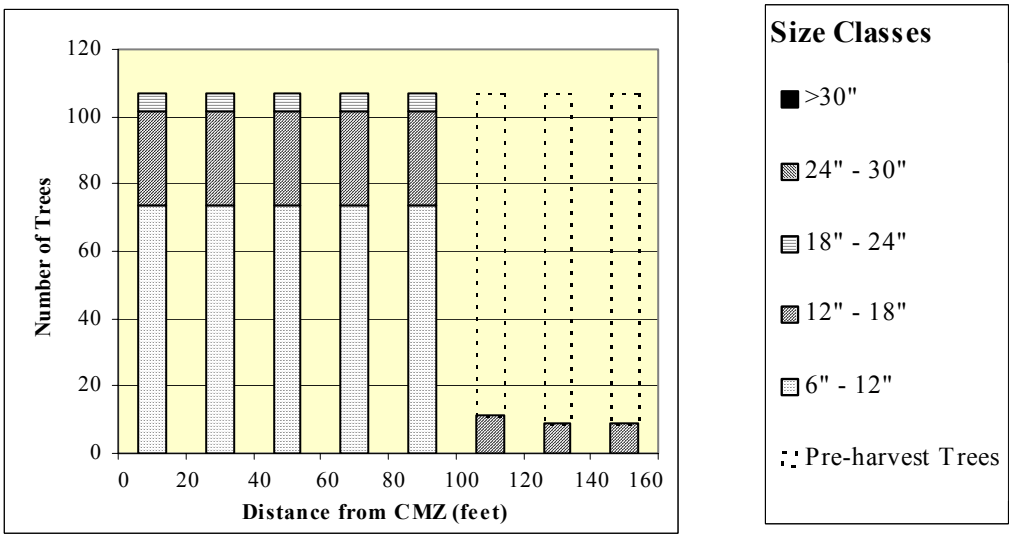
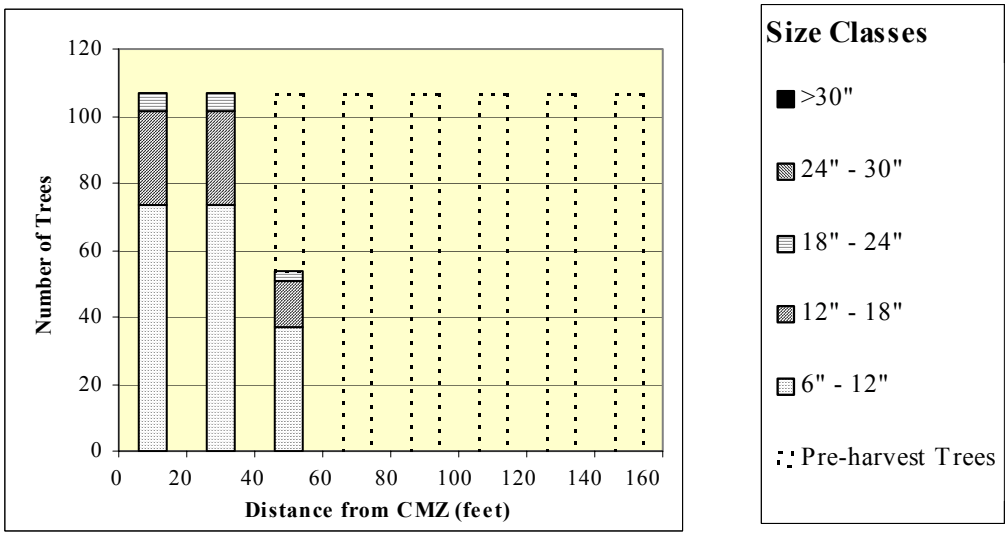


Figure 6e. Westside Trees Remaining in RMZ Under Alternative 2 Along N_p Streams Presented in 20-foot Increments (measured from bankfull width out to the outer edge of the 100-year SPTH) and Totaled by TPA (sub-divided into size class)



3.3.3.5 Assumptions for Alternative 3

- Alternative 3 was modeled assuming no harvest within the RMZ adjacent to the stream, and clearcut harvest outside of the RMZ but within 1 SPTH.
- The width of the no-harvest buffer was determined by stream gradient: a no-harvest buffer of 200 feet around streams with a gradient less than 20 percent, 100 feet around streams with a gradient between 20 percent and 30 percent, and 70 feet around streams with a gradient greater than 30 percent.

3.3.3.6 Outcome for Alternative 3

Tables 19 and 20 present the leave tree density in trees per acre (TPA) remaining in each RMZ band after Alternative 3 prescriptions were modeled using the westside representative stand (see Table 13) along streams with 0 to 20 percent, 20 to 30 percent, and >30 percent gradient, respectively. Table 19 presents the results of modeling the RMZ prescriptions along streams 0 to 20 percent gradient. Table 20 presents the results of modeling the RMZ prescriptions along streams 20 to 30 percent and >30 percent gradient.

Figures 7 a, b, and c are bar graphs that displays the leave tree density (in TPA) remaining in the RMZ presented in 20 foot increments from the bankfull width out to the outer edge of the site potential tree height (site class II) after harvest along streams 0 to 20 percent, 20 to 30 percent, and >30 percent gradient. Each bar in the figure is segmented by size class (in dbh).